SAFETY DISTANCES FOR EXPLOSIVE STORAGE MAGAZINES AND PROCESS BUILDINGS

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Abstract – *An explosive detonated within or immediately nearby a building can cause catastrophic damage to the building's external and internal structural frames, collapsing of walls, blowing out of large expanses of windows, and shutting down of critical life-safety systems. For an accidental explosion which is caused during the manufacturing, or maintenance process in a building, the surrounding building structures should not be affected or damaged and should not affect the human life. To overcome this, the constructions should be beyond the safety circle where the final pressure is within acceptable limits. A particular explosion will have some safety circle within which the effect will be critical for the survival of human beings and other structures. This region will be dangerous for the human life to survive. The structures like offices and dwelling units should be constructed such that they are beyond the safety circle. In an explosion there will be pressure beyond the safety circle, it has less effect when compared to the pressure inside the safety circle. The pressure is a function of quantity of Explosive and the Distance from Ground Zero. In this project we will establish the safety circle radius for different quantities of explosives such that the pressure outside the circle is within prescribed limits for human dwellings and other storage buildings. Further thousand kilograms of TNT (Trinitrotoluene) is analyzed in ANSYS for explosion for which different reflected pressures are obtained at different protection levels. These values are converted into absolute pressures, which are incident pressures. Thus we use that data to find the safe distances manually where the pressure is limited*.

Key Words: **Safety circle1, TNT2, ANSYS3, Protection level4**

1.INTRODUCTION

Internal blast loads consist of unvented shock loads and very long duration gas pressure which are a function of the degree of containment. The magnitude of the leakage pressure will usually be small and will only affect those facilities immediately outside the containment structure. When an explosion occurs within a structure, the peak pressures associated with the initial shock front (free-air pressures) will be extremely high and in turn, will be amplified by their reflections with in the structure. In addition, and depending upon the degree of confinement, the effects of high temperatures and accumulation of gaseous products produced by the chemical process involved in the explosion will exert additional pressure and increase the load duration with in the structure. The combined effects of these pressures may destroy the structure unless the structure is designed to sustain the effects of the internal pressures. Provisions for venting of these pressures will reduce their magnitude as well as their duration.

1.1 ACCIDENTAL EXPLOSIONS

This subsection identifies potential accidental explosions that should be taken into consideration by the design professional team. The intent is to ensure that design professionals especially the structural, mechanical, and electrical engineers and the architect are aware of and provide protection for explosive events other than purposeful, malevolent criminal activity. Explosive events occur as a result of the release of high-energy sources. While traditionally this condition is conceived of as the result of ignition of an accelerant, such as highly flammable liquids, compressed gases, or explosives, other high-energy sources such as steam or water under extreme pressure, chillers, boilers, and other systems routinely found in facilities are also candidates for imparting extraordinary pressures over extremely short durations.

The unabridged edition of the Random House Dictionary of the English Language defines an explosive event as “the act or an instance of exploding; a violent expansion or bursting. . .” and “a sudden, rapid, or great increase.” While the pressures, impulses, and plasma effects associated with an explosive event using extremely high-energy substances such as C4, Semtex, RDX, TNT, or their equivalents, are regarded as upper-level design thresholds for protection, design professionals should carefully review the entire project design with the intention of identifying other building systems and/or programmatic spaces allocated to the storage and/or distribution of substances and materials that could participate in an explosive event. These systems and areas of programmatic use are unlikely to be identified by a traditional security threat and risk assessment, as these activities usually focus upon the purposeful introduction of high-energy explosives as the anticipated design basis threat.

At the earliest possible design phase, the structural engineer, mechanical and electrical engineers, and architect should review the facility design and identify whether any of the systems, equipment, or environmental conditions identify previously are resident within the project scope. This process may involve making specific inquiries of the client, based on the sophistication of their occupancy program, regarding what explosive exposures they know exist, as a result of their detailed familiarity with the facility operations that will occur in the project. The design team should list, as part of the protective design strategy's key design assumptions, the potentially explosive operations, systems, and/or materials and substances that will be present as part of the building's use.

A list of potential explosive event conditions should be created based on the aforementioned plan review and client inquiry. Individual mitigating strategies should be proposed by the design team to address these exposures. This may include the following:

- Elimination and/or reduction of explosive sources and/or quantities from the project.
- The introduction of detection systems to identify the conditions associated with the development of an explosive event condition prior to its detonation and/or release point.
- The introduction of suppression systems capable of reducing the post explosive- event effects.
- The introduction of systems that extract the explosive event agent, upon its detection, and prior to its detonation/ignition.
- The elimination of ignition sources.
- Management of access control, for both persons and vehicles, to preclude entry and accidental initiation of the explosive event.
- The introduction of explosive event pressure relief features that direct the effects of the explosive event in a manner that provides acceptable post event effects.
- Informed placement of potential explosive systems and/or environments so that their post-event effects meet the project's security performance criteria.
- The use of appropriate signage and graphics to prevent occupancies, activities, and/or behavior that could trigger the event.
- The use of hardening to preclude unacceptable and/or disproportionate damage from the event.

These and other mitigating strategies should be considered for implementation by the design team to enhance the facility protection profile.

Internal accidental explosions occur when the explosives have been stored or manufacturing or maintanance takes place. If any chemical explosive stored is in a structure it will have a more chances of accidental explosion. We consider a chemical explosive of TNT ($C_7H_5N_3O_6$). TNT is TriNitroToluene; It can be measured in MT (Millions of tons), KT (Kilo Tons), TJ (Tara Joules). TNT is a unit of explosive quantity. In MODERN PROTECTIVE STRUCTURES there is a concept for conversion of all explosives energy into equivalent TNT. For example 1KG of propane (C_3H_8) is equivalent to 10.25KG of TNT; 1KG of Gasoline (C_8H_{18}) is equivalent to 10.1KG of TNT. The safety factor recommended for design the TNT equivalent weight is increased by 20 percent. This increased charge weight is the "effective charge weight".

1.2 BLAST LOADS

Sample Blast loads on structures can be classified into two following main groups on the basis of the confinement of the explosive charge TM 5-1300(1990).

- **Unconfined explosion**, which include free air burst, air burst and surface burst explosion having un reflected and reflected pressure loads respectively.
- **Confined explosions**, the confined explosions include fully vented explosions, partially confined explosions, fully confined explosions.

Table -1: Classification of blast loading

BLAST LOADING CATEGORIES			
CHARGE CONFINEMENT	CATEGORY	PRESSURE LOADS	PROTECTIVE STRUCTURE
Unconfined Explosions	1. Free Air Burst 2.Air Burst 3.Surface Burst	a. Un reflected b. Reflected b. Reflected	Shelter
Confined Explosions	4.Fully Vented	c. Internal shock d. Leakage	Cubicle
	5.Partially Confined	c. Internal Shock e. Internal Gas d. Leakage	Partial Containment cell (Or) Suppressive Shield
	6.Fully Confined	c. Internal shock e. Internal Gas	Full Containment Cell

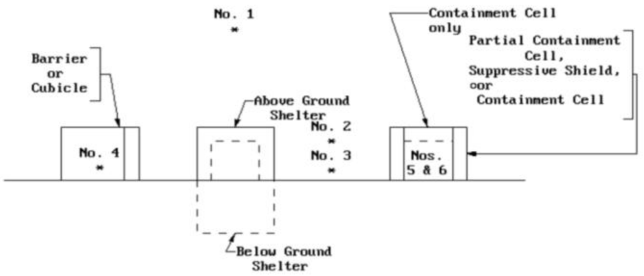

Fig -1: Blast loading

1.3 Pressure Design Ranges

Pressure design is important for blast resistance structures where an engineering analysis of the blast pressure and fragments associated with high explosive detonations acting on protective structures must be made to describe the response of the protective structures to donor output. The response to the blast output is expressed in terms of design ranges according to the pressure intensity, namely, (1) high pressure, and (2) low pressure.

1.3.1 High-Pressure Design Range.

At the high-pressure design range, the initial pressures acting on the protective structure are extremely high and further amplified by their reflections on the structure. Also the durations of the applied loads are short, particularly where complete venting of the explosion products of the detonation occurs. These durations are also short in comparison to the response time (time to reach maximum deflection) of the individual elements of the structures. Therefore, structures subjected to blast effects in the high pressure range can, in certain cases, be designed for the impulse rather than the peak pressure associated with longer duration blast pressures

Fragments associated with the high-pressure range usually consist of high velocity missiles associated with casing breakup or acceleration of equipment positioned close to the explosion. For acceptors containing explosives, the velocities of primary fragments which penetrate the protective structure must be reduced to a level below the velocity which will cause detonation of the acceptor charges. For personnel or expensive equipment, the possibility of fragment impact on the acceptor must be completely eliminated. Also associated with the "close-in" effects of a high-pressure design range are the possible occurrences in Spalling of concrete elements. Spalling is generally associated with the disengagement of the concrete cover over reinforcement at how the acceptor side of a protective element. Spalling can be a hazard to personnel and sometimes to equipment but seldom will result in propagation of explosion of an acceptor system.

1.3.2 Low-Pressure Design Range

Structures subjected to blast pressures associated with the low-pressure range sustain peak pressures of smaller intensity than those associated with the high-pressure range. However, the duration of the load can even exceed the response time of the structure. Structural elements designed for the low-pressure range depend on both pressure and impulse. In cases where the peak pressure is relatively low and the explosive charge is very large (several hundred thousand pounds of explosive) the duration of blast pressures will be extremely long in comparison to those of smaller explosive weights. Here the structure responds primarily to the peak pressure in a manner similar to those structures designed to resist the effects of nuclear detonations. This latter case, although seldom encountered, is sometimes referred to as the "very low-pressure range."

Since the low-pressure design range is involved in the design of shelter type structures, donor fragmentation is of concern. Secondary fragments formed from the break-up of donor structures can produce minor damage to a shelter. These fragments generally have a large mass but their velocities are generally much less than those of primary fragments.

Table -2: Parameters Defining Pressure Design Ranges

Pressure Design Range	**High**	**Low**	**Very Low**
Design Load	IMPULSE	PRESSUR-IMPULSE	PRESSURE
Incident Pressure	>>100 psi	<100psi	<10psi
Pressure Duration	SHORT	INTERMEDIATE	LONG
Response Time	LONG	INTERMEDIATE	SHORT
t_m/t_0	$t_m/t_0>3$	$3>t_m/t_0>0.1$	$t_m/t_0<0.1$

1.4 INTRODUCTION OF SAFETY DISTANCES

The purpose of applying Hazard Division of Mass explosion quantity-distances between PES (potential explosion site) and ES (exposed site) is to ensure that the minimum risk is caused to personnel, structures and facilities. In principle, those functions and facilities not directly related to operating requirements or to the security of ammunition and explosives should be sited at or beyond the Inhabited Building Distance.

In practice, it may not always be possible to provide this level of protection and some activities and facilities will of necessity be sited at less than the Inhabited Building Distance. In other cases, the nature of the facility or structure requires that greater protection than that afforded by the Inhabited Building Distance should be provided. Damage to buildings and injury to personnel can result from either blast overpressure effects or from projections (ammunition fragments and building debris from the PES). The severity of the effects will be dependent on both the type of structure at the PES and at the ES. The levels of damage considered in this section are when the PES is an:

1. Open or lightly confined stack of ammunition and explosives.

2. Earth-covered building containing ammunition and explosives.

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2. EXPLANATION

Explosive manufacturing and storage facilities are constructed so that they provide a predetermined level of protection against the hazards of accidental explosions. These facilities consist of three components.
From UNIFIED FACILITIES CRITERIA (UFC 3-340-02,5 December 2008) discussed in that

- The Donor system-Amount, type and location of the potentially detonating explosive which produces the damaging output.
- The Acceptor system-Personnel, equipment, and acceptor explosives which requires protection.
- Protection system-Protective structure, structural components or distance necessary to shield against or attenuate the hazardous effects to levels which are tolerable to the acceptor system.

2.1 Donor system

The donor system includes the type and amount of the potentially detonating explosive as well as material which, due to their proximity to the explosive, become part of the damaging output. The output of the donor explosive includes blast over pressures, primary fragments resulting from cased explosives and secondary fragments resulting from materials in the immediate vicinity of the donor explosive. Other effects from the donor include ground shock, fire, heat, dust, electromagnetic pulse, etc.

The explosive properties, including the molecular structure (monomolecular, bimolecular, etc.)Of the explosive, shape and dimensional characteristics, and the physical makeup (solid, liquid, gas) of the charge, determine the limitation of the detonation process. These limitations result in either a high- or low-order detonation.

The chemical and physical properties of the donor explosive determine the magnitude of the blast pressure whereas the distribution of the pressure pattern is primarily a function of the of the location of the donor explosive relative to the components of the protective facility. The mass –velocity properties of the primary fragments depends upon the properties of the donor explosive and the explosive casing, while, for secondary fragments, their mass-velocity properties are functions of the type of fragment materials (equipment, frangible portions of the structure, etc.), their relative position to the donor explosive, and the explosive itself.

2.2 Acceptor system

The acceptor system is composed of the personnel, equipment, or explosives that require protection. Acceptable injury to personnel or damage to equipment, and sensitivity of the acceptor explosive(s), establishes the degree of protection which must be provided by the protective structure. The type and capacity of the protective structure are selected to produce a balanced design with respect to the degree of protection required by the acceptor and the hazardous output of the donor. Protection in the immediate vicinity of the donor explosive is difficult because of high pressures, ground shock, fire, heat, and high speed fragments generally associated with a detonation. Protection can be afforded through the use of distance and/or small ground motions without direct injury. However, injury can be sustained by falling and impacting hard surfaces.

In order to prevent detonation, sensitive acceptor explosives must be protected from blast pressures, fragment impact, and ground shock whereas "insensitive" explosives may be subjected to these effects in amounts consistent with their tolerance. The tolerances of explosives to initial blast pressures, structural motions, and impact differ for each type of explosive material with pressure being the lesser cause of initiation. Impact loads are the primary causes of initiation of acceptor explosives. They include primary and secondary fragment impact as well as impact of the explosive against a hard surface in which the explosive is dislodged from its support by pressure or ground shock and/or propelled by blast pressures.

2.3 Protective systems

Personnel, equipment or explosives are protected from the effects of an accidental explosion by the following means:
(1).Sufficient distance between the donor and acceptor systems to attenuate the hazardous effects of the donor to a level tolerable to the acceptor.
(2). A structure to directly protect the acceptor system from the hazardous output of the donor system.
(3). A structure to fully contain or confine the hazardous output of the donor system.
(4). A combination of the above means.

Protective structures can be classified as shelters, barriers or containment structures. Protection is provided by each structure in three distinct manners.

2.4 Containment type structures.

These structures are designed to prevent or limit the release of toxic or other hazardous material to a level consistent with the tolerance of personnel. These structures generally are designed as donor structures and can resist the effects of "close-in" detonations.

2.5 Shelters

Shelters provide protection for personnel, valuable equipment and extremely sensitive explosives. Shelters, which are usually located away from the explosion, accomplish this protection by minimizing the pressure leakage into a structure, providing adequate support for the contents of the structure, and preventing penetration to the interior of the structure by high-speed primary fragments, and/or by the impact of fragments formed by the breakup of the donor structure. Protection against the uncontrolled spread of hazardous material is provided by limiting the flow of the dangerous materials into the shelter using blast valves, filters, and other means.

2.6 Barriers

Barriers act as a shield between the Donor and Acceptor.

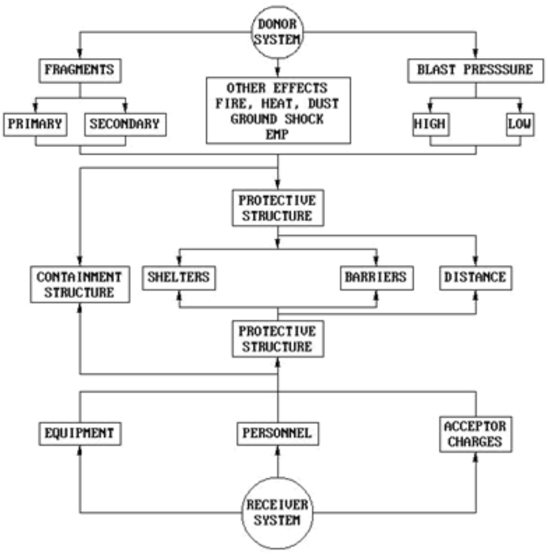


Fig -2: Explosive Protective System

Table -3: Characteristic Properties of Typical Explosives

Explosive	ρmax (g/cm3)	Di at ρmax (km/sec)	Qd (kJ/g)
AN (Amon./Nit.)	1.73	8.51	1.59
Composition C-4	1.59	8.04	5.86
Nitro-glycerine	1.60	7.58	6.80
Nitromethane	1.13	6.29	6.40
Nitrocellulose	1.66	7.30	10.60
Pentolite (50/50)	1.70	7.53	5.86
PETN	1.77	7.98 - 8.26	6.12 - 6.32
RDX	1.76 - 1.80	8.7 - 8.75	5.13 - 6.19
TNT	1.64	6.95	4.10 - 4.55

ρmax = explosive density.

Di = detonation velocity.

Qd = heat of detonation.

3. EXPERIMENTATION - Safety distances and Allowable incident over pressures for different structural conditions.

3.1 EXPLOSIVE WORKSHOPS

In NATO there is an empirical formula for finding the safety distance from Potential Explosive Site (PES) to Exposed Site (ES). Where exposed site is EXPLOSIVE WORKSHOP.

Distance for Explosive workshop is = **8.0***$Q^{\frac{1}{3}}$

Where **8.0***$Q^{\frac{1}{3}}$ is safety distance in meters and **Q** is quantity of TNT in kilograms. Calculating the peak incident allowable pressure at a distance of **8.0***$Q^{\frac{1}{3}}$ from center of PES using procedure given in UFC 3-340-02.

The safety distances and allowable pressures for different quantities of TNT are represented below

Table -4: Safety Distances of different TNT

TNT in kilograms (Q)	Distance of safety location in Meters $(8.0*Q^{\frac{1}{3}})$	Distance of safety location in Feet's
1	8	26.2467
10	17.2354	56.5466
50	29.472	96.6929
100	37.133	121.827
500	63.496	208.32
1000	80	262.4672

For 1000kg of TNT

Consider charge weight = 1000kg
= 1000*2.204622622 lb
= 2204.622622 lb

W = 1.20*(charge weight) = 1.20*2204.622622
= 2645.54658 lb

Distance from center of potential explosive site to

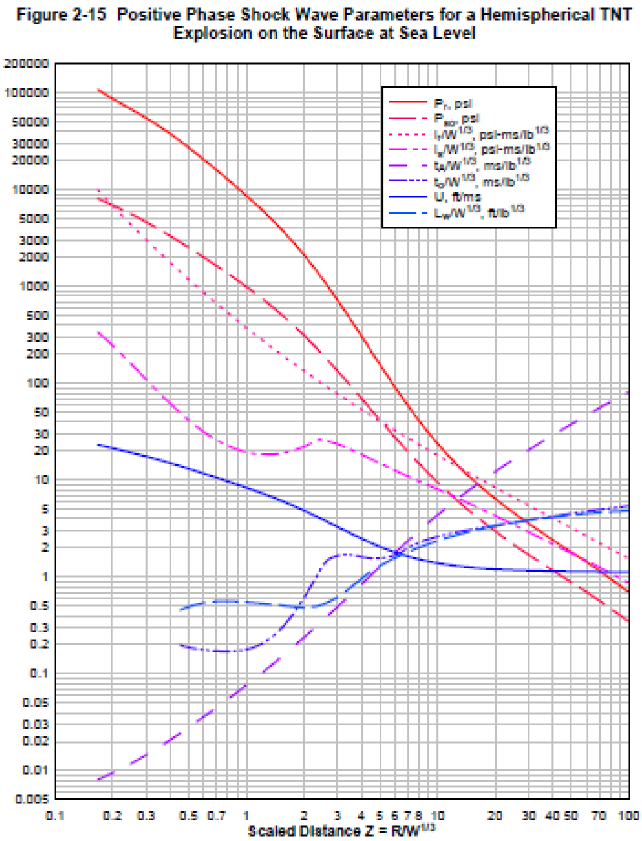
Explosive workshop (R_G) = 262.467191 ft

For a point of interest $Z_G = \frac{R_G}{W^{\frac{1}{3}}}$

$$= \frac{262.467191}{2645.54658^{\frac{1}{3}}}$$

= 18.9773 ft/ (lb^1/3)

From graph - 1 P_{SO} = 3.2 Psi
P_{SO} = 3.2*0.0689476
= 0.2206 bar



Graph-1: Shock wave parameter

Table -5: Allowable pressures at safety distances

TNT in kilograms (Q)	Distance of safety location $(8.0*Q^{\frac{1}{3}})$		Allowable pressure from centre of PES to ES.	
	Meters	Feet's	Bar	psi
1	8	26.2467	0.2206	3.2
10	17.2354	56.5466	0.2206	3.2
50	29.472	96.6929	0.2206	3.2
100	37.133	121.827	0.2206	3.2
500	63.496	208.32	0.2206	3.2
1000	80	262.467191	0.2206	3.2

3.2 STRUCTURES AND FACILITATES IN THE ADMINISTRATIVE AREA OF A DEPOT

Structures and facilities in the administration area of a depot or factory with a considerable number of occupants

Where **22.2*** $Q^{\frac{1}{3}}$ is safety distance in meters and Q is quantity of TNT in kilograms. Calculating the peak incident allowable pressure at a distance of **22.2*** $Q^{\frac{1}{3}}$ from center of PES using procedure given in UFC 3-340-02.

Table -6: Safety Distances of different TNT

TNT in kilograms (Q)	**Distance of safety location in Meters (22.2*** $Q^{\frac{1}{3}}$**)**	**Distance of safety location in Feet's**
1	22.2	72.835
10	47.828	156.916
50	81.7855	268.3251
100	103.0433	338.06857
500	176.2015	578.089
1000	222	728.3465

For 1000kg of TNT
Consider charge weight = 1000kg
= 1000*2.204622622 lb
= 2204.622622 lb
W = 1.20*(charge weight)
= 1.20*2204.622622
= 2645.54658 lb
Distance from center of potential explosive site to explosive workshop (R_G) = 728.3465 ft

For a point of interest $Z_G = \frac{R_G}{W^{\frac{1}{3}}}$

$$\frac{728.3465}{2645.54658^{\frac{1}{3}}}$$

= 52.662 ft/ (lb^1/3)

From graph 1
P_{SO} = 0.84 Psi
P_{SO} = 0.84*0.0689476 = 0.05791 bar

Table -7: Allowable pressures at safety distances

TNT in kilograms (Q)	Distance of safety location (22.2* $Q^{\frac{1}{3}}$)		Allowable pressure from centre of PES to ES.	
	Meters	Feet's	Bar	psi
1	22.2	72.835	0.05791	0.84
10	47.828	156.916	0.05791	0.84
50	81.7855	268.3251	0.05791	0.84
200	103.0433	338.06857	0.05791	0.84
500	176.2015	578.089	0.05791	0.84
1000	222	728.3465	0.05791	0.84

3.3 UNMANNED BUILDINGS CONTAINING IMMEDIATE REACTION FIRE-FIGHTING APPLIANCES

For UNMANNED BUILDINGS CONTAINING IMMEDIATE REACTION FIRE-FIGHTING APPLIANCES distance is given as = **7.2*** $Q^{\frac{1}{3}}$

Where **7.2*** $Q^{\frac{1}{3}}$ is safety distance in meters and **Q** is quantity of TNT in kilograms. Calculating the peak incident allowable pressure at a distance of **7.2*** $Q^{\frac{1}{3}}$ from center of PES using procedure given in UFC 3-340-02.

Safety distances and allowable pressures for different quantities of TNT are found.

Table -8: Safety Distances of different TNT

TNT in kilograms (Q)	Distance of safety location in Meters (7.2* $Q^{\frac{1}{3}}$)	Distance of safety location in Feet's
1	7.2	23.622
10	15.512	50.8924
50	26.525	87.0243
100	33.419	109.6424
500	57.146	187.487
1000	72	236.221

For 1000kg of TNT

Consider charge weight = 1000kg
= 1000*2.204622622 lb
= 2204.622622 lb

W = 1.20*(charge weight)
= 1.20*2204.622622
= 2645.54658 lb

Distance from center of potential explosive site to explosive workshop (R_G) = 236.221 ft

For a point of interest $Z_G = \frac{R_G}{W^{\frac{1}{3}}}$

$= \frac{236.221}{2645.54658^{\frac{1}{3}}}$

= 17.08 ft/ (lb^1/3)

From graph 1
P_{SO} = 0.248 bar

Table -9: Allowable pressures at safety distances

TNT in kilograms (Q)	Distance of safety location ($7.2*Q^{\frac{1}{3}}$)		Allowable pressure from centre of PES to ES.	
	Meters	Feet's	Bar	Psi
1	7.2	23.622	0.248	3.6
10	15.512	50.8924	0.248	3.6
50	26.525	87.0243	0.248	3.6
100	33.419	109.6424	0.248	3.6
500	57.146	187.487	0.248	3.6
1000	72	236.221	0.248	3.6

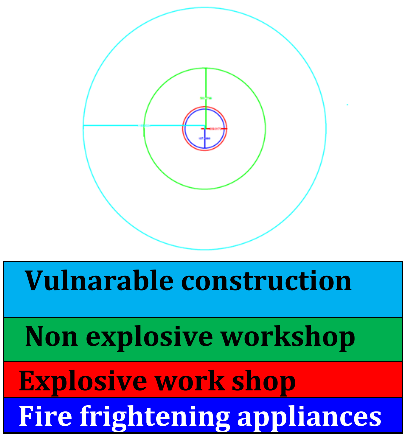


Fig -3: Safety distances for different structural conditions.

4. RESULTS AND DISCUSSIONS

BLAST ANLYSIS ANSYS REPORT.

4.1 INTRODUCTION

Blast analysis has been modelled and analysed in 2D using AUTODYN/EXPLICIT model.
The following plan is shown in fig 3.
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4.2 ANSYS-AUTODYN MODEL

The analysis described here was conducted using AUTODYN. It is based on explicit finite difference, finite volume and finite element (FE) techniques that use both mesh-based and mesh-free numerical methods. The software is based on classical continuum mechanics, which are used to describe the dynamics of a continuous media with a set of differential equations established through the application of the principles of conservation of mass, momentum and energy from a macroscopic point of view. This is an explicit analysis tool for modelling non-linear dynamics of solids, fluids, gas and their interaction. It is based on explicit finite difference, finite volume and finite element techniques that use both mesh-based and mesh-free numerical methods. It provides multiple solvers such as FE, Euler and SPH. Each of these solvers has unique capabilities and limitations.

4.3 GEOMETRY

1. 2D model of 1000kg with pressure readings at various intervals (Safety distances in meter) as listed in table10 is used for simplicity (The symmetry is used in X-direction).
2. The Surrounding Air and TNT are modelled in Autodyn to predict the actual behavior of the blast.
3. The Soil has been modelled in Ansys and TNT and surrounding Air is modelled as Euler multi-material.
4. Structured mesh is used for Euler elements for TNT, Air and Soil.
5. The Structure is modelled with reasonable number of elements in order to predict reasonable material flow.
6. Surrounding Air dimensions
    a. In Y-Direction up to 50m in height from ground.
    b. In X-Direction up to 600 m.

And allowable pressures for different quantities of TNT are found.

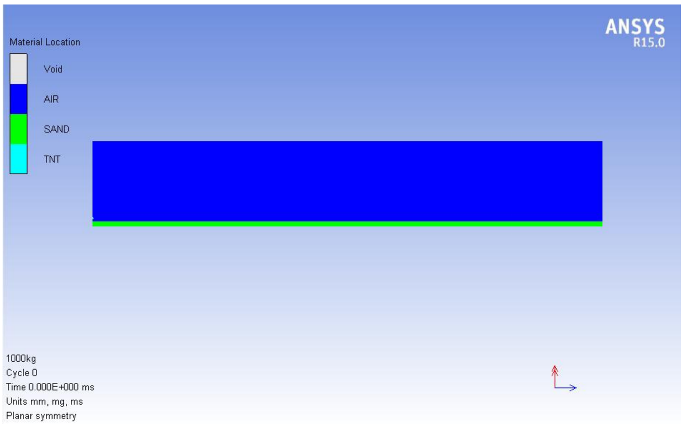

Fig -4: Ansys 2D Model

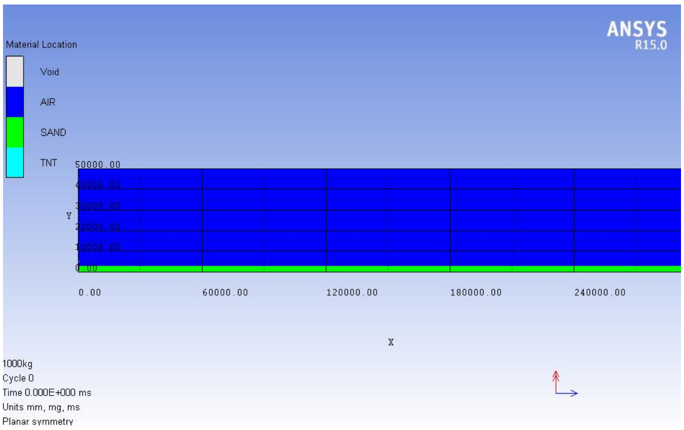

Fig – 5: Model showing dimensions of environment

4.4 BOUNDARY CONDITIONS

1. For surrounding Air, Flow-Out boundary condition is used at the boundaries of the model.
2. Fixed Boundary condition used for soil base.

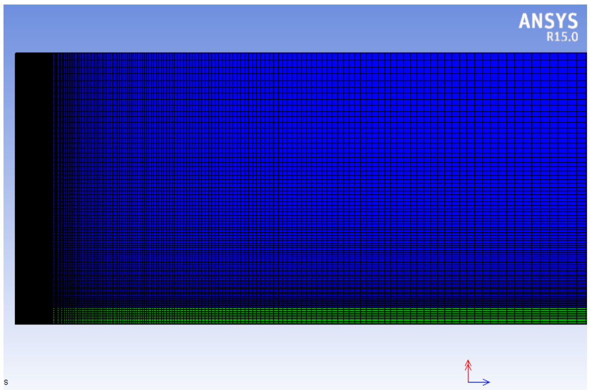

Fig – 6: Grid plot

4.5 ANALYSIS

Explosion of 1000kg of Spherical TNT is considered at the axis of symmetry and at a height of 2.5m from ground. The Analysis is carried out by modeling of TNT and Air Environment. The analysis consists of the simulation of explosion itself from the detonation instant and the effect of interaction with ground of the blast wave generated by the explosion.

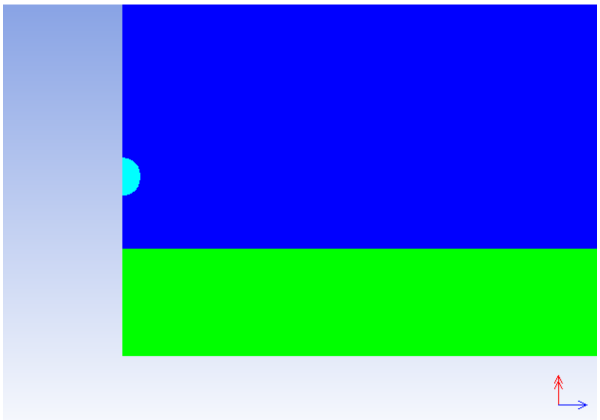

Fig – 7: Generation of 1000kg explosion

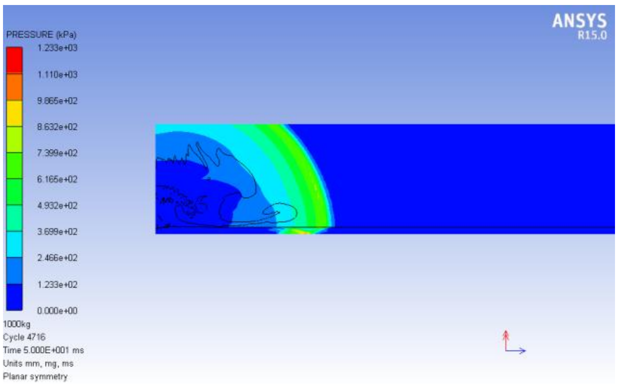

Fig – 8: Pressure plot in 2D Model at 50ms

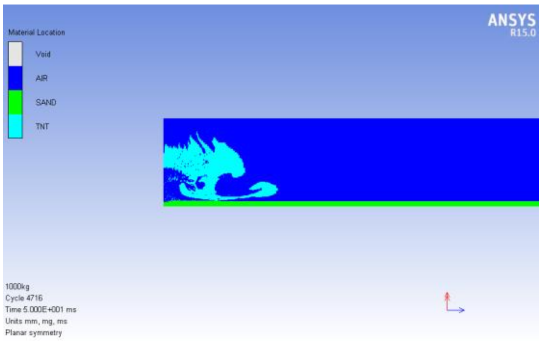

Fig – 9: Location of Explosion at 50 ms

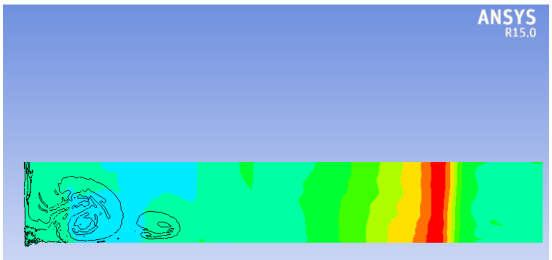

Fig – 10: Pressure plot at 350 ms

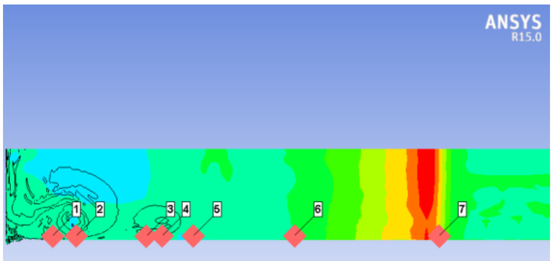

Fig – 11: Pressure recording Plot

Table -10: Results of Reflected pressures obtained from ANSYS

S.NO	SAFETY DISTANCES IN METER	ARRIVAL TIME IN MILLI SECONDS	REFLECTED PRESSURE FROM CENTRE OF PES to ES in MPa
1	24	23.7	0.6
2	36	48.53	0.2054
3	72	140.19	0.05653
4	80	161.7	0.04688
5	96	205.37	0.0345
6	148	350	0.0207
7	222	562.4	0.0124
8	444	1201	0.0048
9	555	1527	0.00296

Table -11: Allowable pressure values from reflected pressures of ansys using graph-1

S.NO	SAFETY DISTANCES IN METER	REFLECTED PRESSURES FROM ANSYS		ALLOWABLE PRESSURE In	
		MPa	Psi	Psi	bar
1	24	0.6	87.022	27.23	1.878
2	36	0.2054	29.8	11.312	0.78
3	72	0.05653	8.2	3.67	0.26
4	80	0.04688	6.8	3.26	0.225
5	96	0.0345	5	2.436	0.168
6	148	0.0207	3	1.392	0.096
7	222	0.0124	1.8	0.7397	0.051
8	444	0.0048	0.7	0.313	0.0216
9	555	0.00296	0.43	0.2262	0.0156

Table -12: Allowable pressure and arrival times at safety distances

S.NO	SAFETY DISTANCES IN METER	ARRIVAL TIME IN MILLI SECONDS	Allowable pressure from centre of PES to ES in bar
1	24	23.7	1.878
2	36	48.53	0.78
3	72	140.19	0.26
4	80	161.7	0.225
5	96	205.37	0.168
6	148	350	0.096
7	222	562.4	0.051
8	444	1201	0.0216
9	555	1527	0.0156

5. CONCLUSIONS

1. All the results are analyzed for 1000 kilograms of TNT.
2. For unmanned buildings containing immediate reaction fire-fighting appliances its allowable pressure is **0.26**bar and safety distance is **72**Meters, pressure wave reaches this distance at **140.19** mille second.
3. For Explosive Workshops its allowable pressure is **0.225**bar and safety distance is **80**Meters, pressure wave reaches this distance at **161.7** mille second.
4. For Structures and facilities in the administration area of a depot or factory(Main office buildings, Non-explosives workshops, Mess halls and kitchens, number of occupants more than 20, Manned fire

stations, Central heating plants, Gasoline storage and dispensing facilities etc.) Its allowable pressure is **0.051**bar and safety distance is **222**Meters, pressure wave reaches this distance at **562.4** mille second.

5. For facilities of especially vulnerable construction or public importance(Large factories of vulnerable construction, Multi-storey office or apartment buildings of vulnerable construction, Large hospitals, Major traffic terminals, Major public utilities etc.) Its allowable pressure is **0.021**6bar and safety distance is **444**Meters, pressure wave reaches this distance at **1201** mille second.

6. Safe distance is the limiting distance between the potential explosive site to Exposed site beyond which structure has no major effect due to the explosion.

7. Safety distance will vary with quantity of explosion but the limiting pressure of a exposed sites is constant.

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